

Section 3: Parts A-E (Notes and Journal Answers)

Parts A-E are an exploration of the term “magnitude” in astronomy.

Part A - Introduction

The introduction helps the students review what the goal is for the entire Exploration.

Journal Questions:

1. Without looking back, write a definition for rotational period in the Journal Box below.

2. Then, briefly describe the steps you would take to find the rotational period of a REAL asteroid, including what needs to be measured.

1. *Rotational period is the time for one complete rotation on an internal axis.*
2. *To find the rotational period of an asteroid, one must take a series of observations, usually over one night. Then:*
 - a. *Locate the asteroid in each image*
 - b. *Measure its brightness, and the brightness of a standard star in each image.*
 - c. *Once the apparent magnitude has been calculated, plot it against the time of the observation.*
 - d. *Analyze the plot (light curve).*

You might want to discuss the goals for this module as stated in this first section. It will help to keep these in mind as they work through the exercises of Section 3.

Part B - Magnitude

This part focuses on the magnitude scale used in astronomy. The questions should help them understand this scale. Encourage discussion and try to get everyone involved.

Imagine three stars: Star A has a magnitude of 2. Star B has a magnitude of 5 and Star C has a magnitude of 9.

1. *Which star is the brightest?*
2. *Which star(s) could have been in the catalog that Hipparchus made?*
3. *Do you think it would be more or less difficult for a person who had never seen stars to understand the magnitude scale? Why?*

4. What do you think it means if the magnitude has a negative sign, for example, -2.5?

Answers:

- 1. Star A is the brightest since it has the lowest number.**
- 2. Hipparchus only used 1st -6th, where 6th class stars were the dimmest stars a human could see. So star C was NOT in the catalog since it is a magnitude 9.**
- 3. This could be answered either way depending on the explanation. For example, the idea of a race can be used, but maybe just looking at stars to see their difference might be harder.**
- 4. If the magnitude is negative, the star is even brighter. For example, our Sun is -26.5 on the magnitude scale.**

MORE JOURNAL QUESTIONS:

5. Below is a list of four objects and their apparent magnitudes. They are listed in order of their distance from Earth.

- a) Full Moon: -12.5**
- b) Sun: -26.7**
- c) Neptune: 7.8**
- d) Rigel(star): 0.13 (a very bright bluish star in the constellation Orion)**

A. Think about what you know about each object. Now make a new list, from most bright to least bright, of how each object would appear if they were the same distance away from you. (This is actually called the *ABSOLUTE* magnitude: how bright the object would appear if it were a standard distance of 10 parsecs from Earth. If you do not know what a parsec is, do a quick search!)

B. Now think about how they appear to someone on Earth, in other words their *APPARENT* magnitude. Using the numbers given, list in order from most bright to least bright appearing.

C. Why are the two lists different?

Answers:

- A. Rigel would be the brightest, then the sun, the moon, and finally Neptune.**

- B. Most bright appearing is the Sun, then the moon, then Rigel, then Neptune. Basically the order of their apparent magnitude.**
- C. The two lists are different because distance affects how they appear to us. A very bright object further away appears dimmer to those on Earth. The sun is a good example, it is obviously the brightest appearing, but if it were at a distance 10 parsecs (32.6 light years), it would appear (have a visual magnitude) of 4.6, a relatively dim star. This is the sun's absolute visual magnitude.**

Part C - More on Magnitudes

The definition is five magnitudes = a brightness difference of 100. This is a multiplicative scale (really a logarithmic). The purpose of the activities is to get a feel for the difference between a multiplicative scale and a linear scale.

Now, imagine a staircase where your total height after each step is multiplied by the same amount. What would it feel like walking up those steps? (Comment in journal below).

Try to get the kids to visualize this. Maybe draw a staircase on the board and then make it tactile with masking tape, etc.

a. Can you figure out the mathematical relationship between 100, 2.512 and the magnitude difference between one and six? Comment in the JOURNAL below.

a.) 2.512 is the 5th root of 100 (approximately). It is actually 2.511886432. Have them use their calculator to check and find this!

QUORUM ACTIVITY

Let's explore further, using Quorum to construct our "steps".

If the students are still not comfortable with Quorum, help them out and have them do the activity as a group (but still have everyone type in their own box). They are doing this for 10 steps, but only six are done for them. Remember, the commands are available as a text file in a PDF.

JOURNAL QUESTIONS

1. Everyone should use the screen reader mode (or "voiceover" if using a Mac) to listen to the command line to calculate the height of step 10. If you have never used this before, ask for help in locating it on your computer.

Record, in the Journal Box below, three adjectives that describe the experience.

2. Imagine now that you rely on screen readers to review code. Think of another way to code this that would be easier to listen to. Discuss with your group.

3. Is the height of that final step above the floor what you expected?

Answers:

- 1. Go to settings on the device and find accessibility, or ease of access, etc. Different devices call it different things! Once they have it turned on, listen to the command line and then describe their experience with the 3 adjectives.*
- 2. This is a math exercise. The group could come up with code that uses powers, etc.*
- 3. A few adjectives here would be good!*

They should copy and paste the console output into their own Journal.

OPTIONAL HANDS ON ACTIVITIES

1. Spaghetti Noodle Break

This is effective if they compare the multiplicative scale to an additive scale as in part c of the activity.

2. Glass gems drop:

Again, hearing the difference between the multiplicative scale and additive scale is instructive.

3. Spring Push (a 3D model has been developed, please order from GLAS)

Part D - Standard Stars

JOURNAL QUESTIONS

1. Imagine two objects that are close together. One object is a standard star. What would we need to do if we want to determine if the second, unknown object, varies in brightness?

2. Why do we need a standard star in the image when we are creating a light curve for an asteroid?

1. *You would need to take two images and compare the ratios of counts . If the ratio is the same, the second object has not varied - yet. Ask the students how many images they should take to convince themselves it's stable.*
2. *The standard star should stay in all the asteroid images if the rotation takes place over a 2-5 hour period. Then all you need is to compare ratios from each image to see how the asteroid varies.*

3. If Star A and Star B have a magnitude difference of 7, what is the count or brightness ratio? What does this mean about Star B if we know Star A is brighter?

4. What is the magnitude difference between two objects if the intensity ratio is about 40?

3. $2.512^7 = \text{about } 630$ (the brightness or count ratio)

4. Referring to the step scale they used Quorum to make, it is a difference of 4. Or they could calculate (coming up in the next part): $2.5\log(40)=4$.

Part E - Calculating Magnitudes (Optional)

This is an optional section, but a good one! It gives more practice coding by using the math library.

As a leader, go through the exercises so you are familiar with them.

QUORUM EXERCISE #1

3. *Once you have a successful build, do the problems below. Even though your Quorum code will be seen by the researchers, record your answers in the Journal Box. Compare your answers with the group.*

a) *Given StarA has a magnitude of 8.6 and Star B has a magnitude of 3.2, find the intensity ratio of the two stars. Explain what this ratio means about the two Stars.*

b) *Given Star A has a magnitude of 2.8 and an unknown asteroid has a magnitude of 15.6, find the count ratio. What does your answer mean?*

c) *What could be done if we did not know the magnitude of the asteroid, but we did know the intensity ratio, and we knew StarA was a standard star?*

- a) *The magnitude difference is $|8.6-3.2|=5.4$. Raise 2.512 to this power: $2.512^{5.4} = 145$. This means starA is 145 times dimmer than starB.*

- b) The magnitude difference is $|15.6-2.8|=12.8$. Raise 2.512 to this power: $2.512^{12.8}=132,000$. The asteroid is that much dimmer than the star!**
- c) You could actually look up the magnitude of StarA and then solve for the magnitude of the asteroid since you know all the other variables.**

QUORUM EXERCISE #2

5. Once you have a successful build, do the problems below. Use the same journal box as before.

a) An image is taken of an asteroid and found to have a count of 500. A standard star in the same image has an intensity of 20,000. What is the magnitude difference between the standard star and the asteroid?

b) In another image of the same asteroid, the intensity was found to be 750. The standard star in this image has a count of 21,000. What is the magnitude difference?

c.) Write an additional line of code to find the apparent magnitude of the asteroid if the standard star is know to have an apparent magnitude of 3.8. Then find the apparent magnitude of the asteroid for the two images.

- a) First find the intensity or count ratio: $500/20,000=.025$. Then the difference in magnitudes = $2.512\log(.025)=$ to about 4.**
- b) $2.512\log(750/21000)=3.6$**
- c) A possible additional line or two of code:**
 - i) `number MagStandardStar = cast(number, input("What is the magnitude of the Standard Star?"))`**
 - ii) `number MagnitudeObject1 = magnitudeDiff + MagStandardStar`**
 - iii) `Output MagnitudeObject1`**
 - iv) The magnitude of the asteroid in a)=7.8, and the magnitude of the asteroid in b)=7.4**

Credits: **Innovators Developing Accessible Tools for Astronomy (IDATA)**, officially known as *Research Supporting Multisensory Engagement by Blind, Visually Impaired, and Sighted Students to Advance Integrated Learning of Astronomy and Computer Science*, and the resulting curricular resources, Afterglow Access software, and project research were made possible with support from the U.S. National Science Foundation's STEM+C program (Award 1640131). IDATA institutional collaborators include AUI, GLAS Education, Linder Research & Development Inc., Logos Consulting Group, TERC, University of Nevada – Las Vegas, University of North Carolina at Chapel Hill, and Universidad Diego Portales. Individual consultants on the project include Kathy Gustavson and Alexandra Dean Grossi. IDATA Teacher collaborators in the U.S. include Amanda Allen, Jacqueline Barge, Holly Bensel, Neal Boys, Tim Fahlberg, Kristin Grender, David Lockett, Matthew McCutcheon, Caroline Odden, Michael Prokosch, Kara Rowbotham, Rick Sanchez, and Barbara Stachelski. IDATA Student collaborators in the U.S. include Evan Blad, Naleah Boys, Ellen Butler, Jayden Dimas, Riley Kappell, Joseph Murphy, Logan Ruby, Alex Scerba, Charlize Sentosa, Meg Sorensen, Remy Streichenberger, Trevor Warren, and others. IDATA Undergraduate Mentors include Tia Bertz, Katya Gozman, Chris Mathews,



Kendall Mehling, Andrea Salazar, Ben Shafer, Alex Traub, and Sophia Vlahakis. Special thanks to the IDATA external advisors including Nic Bonne, Al Harper, Sue Ann Heatherly, Russ Laher, Luisa Rebull, Ed Summers, and Kathryn Williamson,